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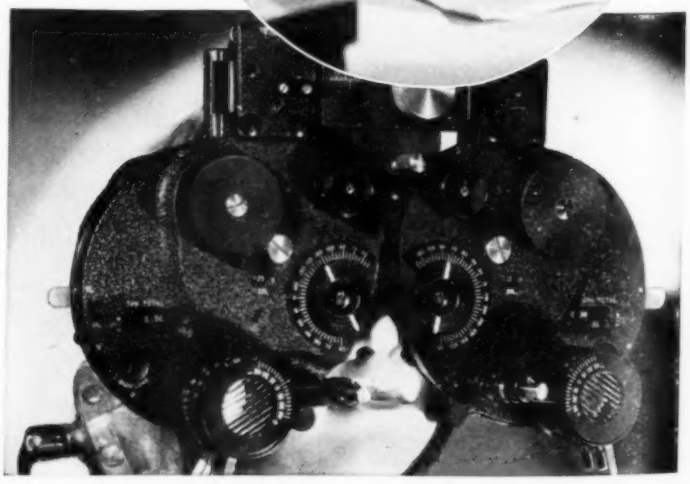

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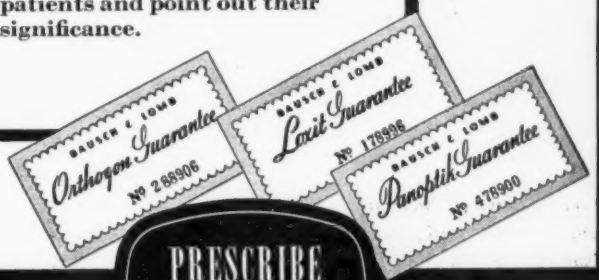

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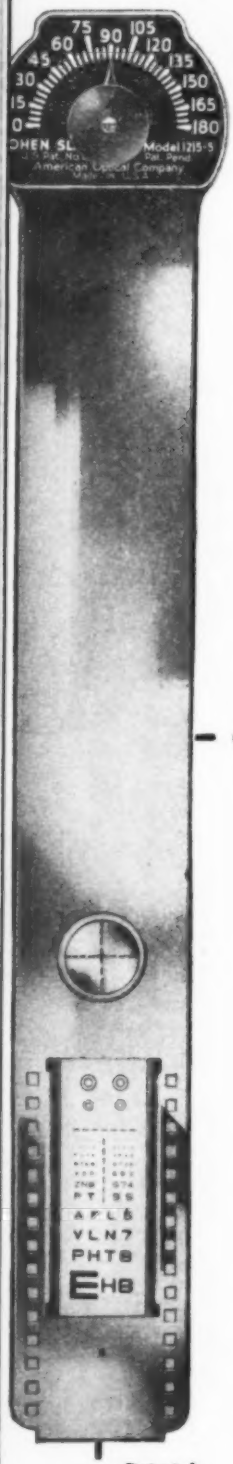

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AMERICAN JOURNAL OF OPTOMETRY

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INVESTIGATION INTO ANOMALOUS CORRECT PROJECTION IN CASES OF CONCOMITANT SQUINTS*

Frederick W. Brock, Opt.D.
New York, New York

PART ONE—THE PROBLEM

Ever since it was discovered that in certain cases of squint a new projection habit had been formed, scientists began speculating as to the mental processes which made it possible for a patient to acquire this strange habit. Such eminent men in the field of opthalmology as Helmholtz, Herring, Javal and Fuchs brought forward their opinions, evolved theories and conducted experiments in order to explain this strange phenomenon. In spite of the fact that for the last century innumerable men have given thought to this matter, we are but little further today in our understanding of how such a mental readjustment is possible.

A good deal of definite knowledge has been accumulated regarding normal binocular vision and from this have sprung several theories regarding anomalous correct projection.

The term "anomalous correct projection" as suggested by Verhoeff[1] is synonymous with "abnormal retinal correspondence," "false macula," "false projection," "secondary retinal correspondence," "incongruous retinas," "anomalous correspondence adapted to the angle of squint."

Duke-Elder[2], in his TEXTBOOK OF OPTHALOMOLOGY, gives a summary of the more or less established facts regarding corresponding retinal points. He writes: "In order to allow the adequate presentation of two harmonious uniocular impressions, the images of points which coincide with each other in the visual fields must fall upon functionally related retinal points. Such points on the two retinae from which images are projected to the same place in the common visual field are called *corresponding* (or identical) points " . . . . . " when the two images of an object fall upon these points, binocular vision is possible; if they do not,

*Submitted for publication November 10, 1938.
[1]Verhoeff, F. H.: Visual phenomena and strabismus, Arch. Ophth. 19-663.
[2]Duke-Elder: Textbook of Ophthalmology. Vol. I, page 1,029 and ff.

as when one eye is pushed out of alignment by the finger, diplopia results. Such non-corresponding points are called *"disparates."*

Duke-Elder then gives his own opinion regarding "anomalous retinal correspondence," in which case, according to him, the fovea of one eye "obviously corresponds" with a peripheral point in the squinting eye. As proof that this is so he gives the following references: Pickford (1842), v. Gräfe (1854), Magel (1861) and Donders (1864). He goes on to say that "such patients are said to acquire an eccentric false macula, which establishes physiological association with the true macula of the other eye, and an entire system of secondary correspondence may appear, an anomalous visual relationship which may become comparatively fixed and which may be capable of mediating full stereoscopic vision." Duke-Elder then mentions the peculiar phenomenon of uniocular diplopia which was first described by Javal (1896) and soon after by Bielschowsky (1898).

The conclusion Duke-Elder draws from these facts is that "correspondence is not an anatomical but a functional attribute: it is not rigidly determined, but is capable of development and alteration."

Although Worth[3] made a definite distinction between "false fixation" and "false macula," claiming that the former is exceedingly common in neglected cases of unilateral squint, while the latter is quite rare, he left no doubt that he considered the "false macula" an acquired condition in those cases, where the angle of squint had remained exactly the same over a period of years and where the suppression of the vision of the deviating eye was "not profound." He said in substance: "The mind sometimes learns to make full allowance for the faulty position of this eye. So that the eccentric image, formed in the deviating eye is mentally projected to the same spot as the true mascular image, formed in the normally directed eye, and is blended with it. This false macula is merely a small area which has escaped the loss of function, which has overtaken the surrounding part of the retina."

This agrees closely with the opinions of Dr. Ernst Fuchs[4] of Vienna, another independent investigator at the turn of the last century who considered it beyond question that a false projection had to be acquired in all instances. He said: "Es unterliegt keinem Zweifel, dass im Beginne des Schielens eben so gut doppelt gesehen wird wie bei der Lähmung eines Augenmuskels." The reason that this had not been universally recognized, he asserted, was the extremely early onset of convergent strabismus: so that the patient, by the time he came under medical observation, had already learned to suppress double vision. He differed from Worth in that he considered the suppression not limited to the squinting eye which receives the foveal image of the dominant eye at a point somewhere to the nasal side of its foveal region, but assumed that the patient learns to

[3]Worth: Squint, its causes, pathology and treatment, page 34.

disregard (abstrahieren) the mental impression of this region without, however, losing consciousness of the foveal impressions of the squinting eye. At the same time, according to Fuchs, the dominant eye suppresses the nasally from the fovea located area corresponding to the fovea of the squinting eye.

Fuchs definitely denied the possibility of any kind of binocular vision in cases of squint and claimed that these patients are no better off than one-eyed persons as far as depth perception and stereoscopic vision is concerned[5]. In his opinion the suppression of one image is, however, confined only to those objects which are within the overlapping area of the two visual fields.

Peckham[6] claims that it takes a person of more than average intelligence to acquire "false projection habit" and that it is an adaptation by patients who can neither learn to ignore the false image nor have sufficient muscle control to straighten their eyes. In "false projection," according to Peckham, the foveal image of one eye and a non-foveal image of the other eye are fused with the resultant increase in form and detail perception in that particular off-foveal area.

Javal reasoned in like fashion when he wrote:[7] "The theory to which I ascribe (l'origine empiristic) is the only compatible one as regards the cases of "incongruous strabismus" of J. Müller and "perverse projection" of v. Gräfe."

Javal had long since noted that in certain cases of concomitant convergent squint with good visual acuity in both eyes, the patient frequently had, as it were, two foci of foveal perception in the extrinsic binocular fiield. He noted, for instance, that if two hands were held in front of such a patient so that each hand intercepted the primary visual axis of his fixing and squinting eye respectively, both hands could be seen with perfect distinctness, although the patient's eyes were completely motionless. Javal could not, however, make himself believe that both eyes sent simultaneous impressions to the brain but assumed that there existed a very rapid alternation: the one eye suppressed, while the other eye had foveal perception, and vice versa[8].

Javal questioned the advisability of using the term "false projection" because, he claimed, in reality this projection was the only correct one as, for the deviating eye, (extrinsic) objects were projected along the direc-

[4]Fuchs, E.: Lehrbuch der Augenheilkunde (1900), page 696 and ff.

[5]ibid, page 697: "Wenn der Schielende mit beiden Augen seiht, gleicht er einem einäugigen darin, dass er so wie dieser keine Tiefenwahrnehmung, kein stereoscopisches Sehen hat."

[6]Peckham: Squints and Heterophorias, page 130.

[7]Javal, E.: Manuel du Strabismus, Paris, 1896, page 48.

[8]ibid, page 278: "D'accord avec le raisonnement, les auto-observations faites par des sujects intelligents nous enseignent que, dans l'experiénce qui précède, les deux mains ne sout *jamais* regardées *simultanément*."

tion of their actual position. This stand has been taken by several later investigators.

Again it was Javal who gave a minute description of a case of uniocular diplopia in conjunction with anomalous projection. The case, which has become since then a "casse célèbre" in opthalmological literature was under both his and von Gräfe's observation.

Helmholtz, on the strength of evidence like this, evolved the so-called EMPIRICAL theory of binocular vision which claims that the sensory correspondence of the two eyes is acquired through learning and training and that, therefore, in certain cases of squint a new sensorial relationship between the two eyes can be developed (which is adapted to the angle of squint).

Herring, however, disputed the correctness of this theory on the basis of facts, such as the semi-decussation of the optic nerves and the hemianoptic scotomas resulting from a lesion on one side of the calcarine cortex. On the strength of this, he advanced his NATIVISTIC theory which claims that the basis for retinal correspondence is innate and therefore cannot be changed at will.

Herring makes a distinction between relative localization and absolute or egocentric localization of outlying objects. If, for instance, a 10° prism base down were placed in front of one's eyes the upward displacement of all extrinsic objects as viewed through these prisms would alter the egocentric localization of these objects but would have no bearing on their relative localization, relative to each other and to the principal visual direction. Herring contends that this relative localization is innate and that only the absolute orientation can be altered by training or circumstances. Herring demonstrated the sensorial relationship between the two eyes by means of after-images and these experiments were later repeated and elaborated upon by other investigators, particularly by A. Bielschowsky who described the procedure as follows:[9] "One may produce in one eye a horizontal and in the other a vertical after-image of a glowing filament, the center of which is concealed by a black ring with a white fixation mark. Everyone with normal retinal correspondence will see in a dark room the positive or in a bright room the negative after-images forming a cross, because the centers are situated on the fovea. Whatever the position of the eyes relative to each other may be, it cannot influence the position of the after images relative to each other as long as the normal retinal correspondence is functioning. One may displace one eye with the finger or with a forceps; the figure of a cross formed by the after-images will remain unchanged, their centers being fixed on the two foveae. The same is true in nearly every case of paretic squint, and, further, in a *minority* of cases of concomitant squint, particularly if the squint has not developed in early childhood. But in most patients who have squinted since early childhood the after-image test gives a different

result." He goes on to say that in these cases the images situated at the foveae are localized according to anomalous correspondence, not in one and the same visual direction, but in different directions; so that the vertical and horizontal after-images of the two eyes do not form a cross but are laterally displaced, forming an angle which closely agrees to the angle of squint. But further on he admits that "many patients who show an anomalous sensorial correspondence with the after-image test will be much surprised, if the test is repeated in exactly the same way in a dark room or with both eyes closed, to observe that sooner or later the position of the after-images relative to each other is different in the individual tests."

Bielschowsky found in the investigation of many hundreds of patients with strabismus only rudiments of binocular vision and only in exceptional cases a certain amount of depth perception which was measurably greater than with the squinting eye occluded.

In weighing all this evidence of extremely contradictory nature one can be sure of little more than the fair certainty that there is an innate retinal correspondence which, in most cases of concomitant squint of long standing, gives way to a secondary anomalous retinal "correspondence" of most perplexing and unstable character.

That this anomalous condition is nothing more than the complete absence of corresponding retinal points in the two eyes with the result that there are no corresponding visual axes in these cases is a new theory which was recently brought forward and substantiated by Dr. Verhoeff of Boston.[1] He made it clear at the outset that "corresponding retinal points" cannot merely be defined as retinal points that are projected to the same space. Verhoeff defines corresponding retinal points as "retinal optical terminals of a pair of corresponding visual axes," when corresponding visual axes are understood to be "any two visual axes that, as visualized from their respective eyes with the aid of suitable objects coincide."

This means that, if in normal retinal projection the right eye focuses on an object A (fig. 1), and another object N is introduced at a definite distance (preferably about 20 ft. away) anywhere within the binocular field, a third object C can be placed in such a way that, as viewed with the right eye, it appears in line with object N. This latter object should be placed close enough to the eye (approximately 4") that the interpupillary distance plays a decisive factor. If now another distant object D and near-object E are placed in such a way, that, as seen from the left eye, they too are in perfect alignment with objects N and C as seen from the right eye; then, if none of these objects are at the crossing point K of these

[1]Bielschowsky, A.: Application of the after-image test in the investigation of squint. Arch Ophth. 17-408.

visual axes, the retinal terminals X_R (of the extended line NC) and X_L (of the extended lines D E) are *corresponding retinal points.*

Verhoeff found that in all instances where the four suitable objects N, C, D and E could be brought in alignment in the above manner, the

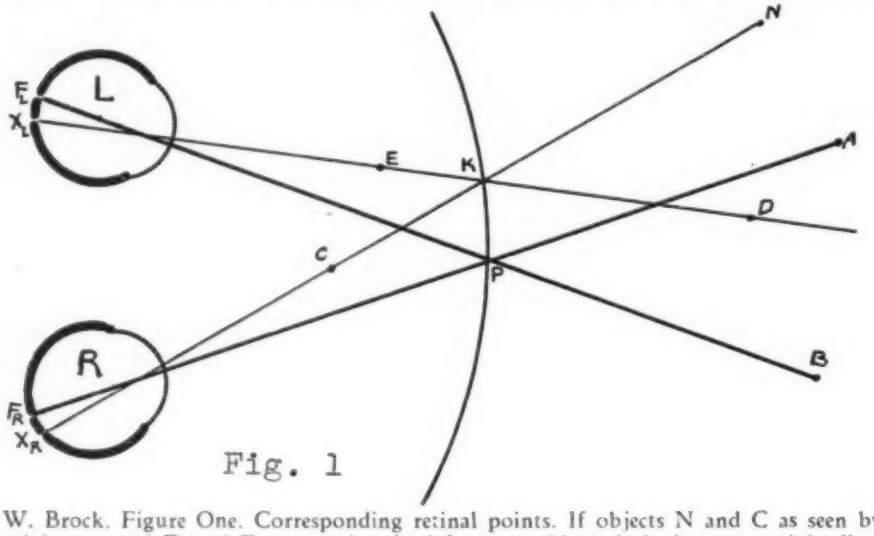

Fig. 1

F. W. Brock. Figure One. Corresponding retinal points. If objects N and C as seen by the right eye and D and E as seen by the left appear binocularly in one straight line. X_R and X_L are corresponding retinal points. (Verhoeff)

foveae F_R and F_L were in all instances corresponding retinal points. In actual tests of this kind it is not necessary to make observations within narrow limits because Verhoeff found that in all cases of anomalous projection visual axes never corresponded within wide limits.

Verhoeff questions the conclusions drawn from the usually employed tests to determine "normal retinal correspondence" or "anomalous retinal correspondence" on the ground that they are usually made under such artificial conditions that it is impossible for the patients to interpret them subjectively with any great assurance. And, indeed, which investigator has not frequently found that patients with anomalous projection cannot definitely state on which side of the fixation object he sees the "secondary" image? This fact alone must make us realize that it is just as difficult for us to understand the mental visual processes of the squinter as it is for him to understand "normal" binocular vision.

Verhoeff's criticisms of the conclusions drawn from the results of the after-image tests of Bielschowsky are that in these tests the depth criteria is completely lost; so that it is possible for the patient to project one or both filaments to the crossing point of his visual axes which in turn would explain why they are seen "superimposed." It is difficult to see how this explanation could hold in a case of divergent strabismus where the crossing point is in back of the eyes: but on the other hand Bielschowsky, in his case histories, did not describe any such case.

Verhoeff criticises the use of instruments like amblyoscopes, stereoscopes, haploscopes, etc., because they are based on the principle of normal projection habits and are highly confusing to patients with anomalous projection.

In analysing the results of his tests Verhoeff concludes that patients with anomalous projection normally use both eyes in binocular vision and that the squinting eye furnishes a much larger part of the binocular visual pattern that reaches consciousness than has heretofore been assumed. He further claims, from the evidence at hand, that both eyes reach consciousness *simultaneously* although the patient invariably credits all his visual sensations to the fixing eye.

Dr. Verhoeff, therefore, comes to the conclusion that "What actually happens in cases of strabismus whether or not projection is correct is that the apparent relative positions are judged from the point of view of the fixing eye."

The anatomic investigations by Henschen[10] and others, as well as the investigations regarding corresponding retinal visual terminals by Herring, Bielschowsky and Verhoeff, tend to show that there is a close retinal correspondence between certain groups (or pairs) of retinal terminals in both eyes and that this correspondence is of unchangeable character. In other words, the relative localization (Herring) in innate, and only the absolute or egocentric localization is amenable to training. This fact has often been lost sight of and certain investigators like Burri[11] have used Stratton's experiment showing that the human being can acquire new tactual and conceptional standards in a reasonably short time, as an argument to prove that retinal correspondence is learned and may be altered. Stratton when wearing glasses which rotated the retinal image 180° found that he could adapt himself to changed egocentric conditions within the week. Such a "reversal" is at times brought about spontaneously by severe toxemias and, indeed, such a case has recently been brought under the writer's own observation. It is, however, quite evident that in cases such as these no new retinal correspondence has to be acquired but only a new standard of orientation.

The essential fact remains that, even if there is no point-to-point retinal correspondence, as some authors claim, and single binocular vision can be retained in certain cases where the foveae do not correspond by several degrees, as Peckham's investigation would prove, these possible variations could not be adequate to account for the lack of double vision in anomalous projection. If, as Helmholtz, Duke-Elder, Peckham and others claim, secondary retinal correspondence of disparate retinal points does exist in certain cases of squint, then we could (and would) expect in these cases a somewhat increased visual acuity or at least an increased mental

[10]Henschen, S. E.: Die Vertretung der beiden Augen in der Sehbahn und in der Schrinde. Arch. F. Ophth. 117:403, 1926.

[11]Burri, Clara: The concept of abnormal retinal correspondence: A theoretical analysis. Arch. Ophth. 19-409.

alertness in the retinal area of the squinting eye in correspondence with the macula of the fixing eye. Peckham claims that he has demonstrated this to be the case, but a good deal of evidence has since accumulated to disprove this assertion.

If, on the other hand, anomalous projection should depend mainly on suppression and particularly on total suppression of the area of the squinting eye corresponding with the macula of the dominating eye (Javal, Fuchs), it might just as reasonably be assumed that this area would, in time, become sub-normally sensitive.

If, however, as Verhoeff claims, there is no definite small area (like the macula) which corresponds visually with the fixation axis of the fixing eye but rather an elongated area extending from the macula of the squinting eye temporally (in convergent squint) toward and beyond the blind spot, how then is it possible for a squinting person with anomalous projection to evaluate correctly the visual impressions of fixated objects produced simultaneously on widely disparate (and constantly changing) retinal terminals in the two eyes?

Verhoeff gives the explanation that the less distinct image is consciously suppressed (or rather replaced) while there still remains a subconscious evaluation of this image. Whether this is actually the case is at the present still a matter of conjecture.

As has already been stated Henschen[10] recently traced the representation of the two eyes in the visual cortex. He found that this area is made up of two main layers, a superficial layer of nerve cells and a deep layer of nerve fibers, which come from the cells of the external geniculate body. The superficial cells again divide into three separate layers which show a very significant arrangement. When both eyes are lost in early life, both the superficial and deep layer become atrophied while the middle layer remains intact. If one eye only is lost, the atrophy extends over the superficial layer on the same side and the deep layer on the opposite side of the lost eye. This suggests strongly that the middle layer is not directly related to either eye but is functionally independent and most likely the final receptor which correlates the cortical stimuli of both the upper and deeper layers which in turn connect with functionally related points of each retina. Henschen assumes that, if fusion is to occur, approximately corresponding cells in the deep and superficial layer must be stimulated. If this is so it must also be assumed that the cerebral termini of retinal points lying on the nasal half of each eye must lay more or less directly under the cerebral termini of their corresponding (conjugate) retinal points from the temporal half of the opposite eye, separated only by the intermediate neuron layer which supposedly accomplishes the unification of the separate impressions of the two eyes.

How such an arrangement would be disrupted by an internal squint is graphically demonstrated in the schematic Figure No. 2. Binocular cortical representations of a single extrinsic object would be laterally displaced in the superficial and deep neuron layer so that "single vision"

would entail an entirely different and oblique net-work of inter-connection. The significant fact, however, is that, even if it were possible (through an extremely complicated and intricate net-work of nerve paths in Henschen's intermediate layer) to coordinate retinal impressions produced on the superficial and deep layer of neurons in continuously shift-

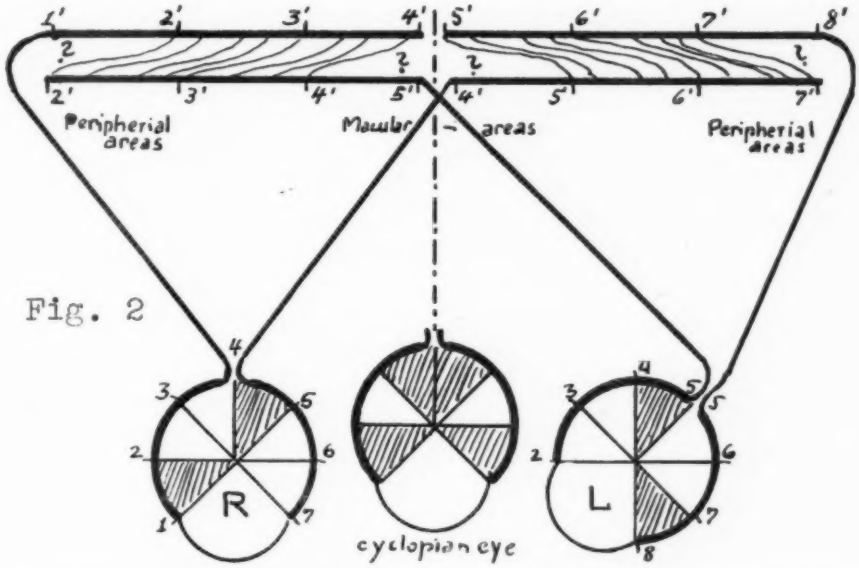

Fig. 2

F. W. Brock. Figure Two. Schematic representation of the three-layer arrangement of the superficial layer of nerve cells in the visual cortex in a case of 45° convergent squint. 1-1, 2-2, etc., are anomalously corresponding retinal points; 1′, 2′, etc., represent their cortical end termini in non-corresponding positions. The shaded areas in the right and left eyes are without by-retinal cortical representation if temporal and nasal halfs are carried to opposite sides of the visual cortex. The cyclopian eye shows these areas combined.

ing positions in regard to each other, there still would remain a large paramacular area in the deep layer devoid of corresponding retinal termini in the superficial layer on either side. That, together with co-existing material shrinkage of the binocular field of both eyes, (see shaded portions in cyclopic eye, Figure No. 2), would leave only a comparatively small area where any unification could be accomplished through the medium of the intermediate neuron layer. How then, can fusion be accomplished?

It can be reasonably assumed that stereopsis is phylogenetically a late development and that some sort of unification of bi-visual impressions was, and still can be, accomplished without it. Third degree fusion does depend almost completely on good macular perception because it utilizes small differences in the visual sensations of the two eyes. The more highly developed this function is, the smaller may be the individual difference of corresponding images without loss of their appreciation. If this is so, it also seems evident that peripherial visual acuity is not ade-

quate to help materially in three dimensional perception and the intricate and precise nerve layer arrangement of Henschen seems of little advantage beyond the macular and immediately paramacular areas. It may be possible therefore that the accurate method of coordination through an intermediate neuron layer is more or less limited to "direct" vision and that off-foveal fusion of images of a single object may be accomplished in a more "primitive" fashion: without the aid of anatomically related end-organs in the cortex exactly corresponding in spatial arrangement to similarly correlated conjugate visual receptors in the two retinae. This would have to be brought about by a brain center of earlier phylogenetic origin (not necessarily located in the calcarine cortex) with the ability to interpret identical double images as belonging to one object in outer space no matter in what positional relation these images present themselves, provided only that they do not vary their relative positions in exactly similar situations. In other words, unification beyond the macular area would depend on a more or less mental but nevertheless subconscious effort (depending on the familiarity of the particular "set" of retinal stimuli utilizing past experiences of similar nature) to determine the position or movement of objects in outward space. While stereoscopic vision in the macular field would depend solely on anatomically correct representation of conjugate retinal sensations in the cortex.

That such a dual-system of "unification" of binocular impressions may very well exist in normal binocular vision suggests itself when one focuses (binocularly) a far distant point and moves an object of great attention value across the primary visual axis of both eyes at a distance of about two feet. It can then be observed that this object is seen singly (in spite of the fact that it does not lay on the horopter) until it approaches very closely to the visual axis of the eye on the same side, when it suddenly and abruptly "doubles" and just as suddenly regains the appearance of a single object shortly after it has passed beyond the primary visual axis of the other eye. This phenomenon cannot be explained by increased visual acuity in the macular and immediately paramacular region of the binocular visual field alone, because when two identical objects are carried across the visual field in the same manner they are easily recognized as a pair even in the more outlying field.

In such a dual-system of "fusion" we would expect second and third degree stereopsis to be the functions of the higher (phylogenetically later) center while simple unification of similar bi-retinal sensations would be accomplished by the lower (phylogenetically older) center, the former extending over a comparatively small central portion of the binocular visual field, the latter extending over its entirety.

It is a fact, known to all who have to do with "fusion training," that stereopsis is not a function mastered in equal degree by all patients. On the contrary, in certain instances it seems to be almost entirely lacking and little amenable to training. It is therefore conceivable that in certain persons with otherwise normal binocular vision the cerebral centre

for stereopsis may be poorly developed or, for some reason or other, remain inactive. If this is so, we would expect these persons to be strongly predisposed to anomalous projection and easy victims to contributing causes like strong refractive errors, fevers and toxemias. I am inclined to be of the opinion that squints are more apt to be caused by a weak or absent "desire" for stereopsis, rather than that weak fusional desires are the results of squints.

Granted a cerebral arrangement such as this, anomalous projection would be expected as a logical end-result in squint cases with weak or absent stereoptic ability and amblyopia ex-anopsia in patients with strong fusion faculties. That amblyopia ex-anopsia and anomalous projection are very often co-existent, especially in cases of long standing, would indicate that a primarily existing strong fusion faculty may, through disuse and positive interference, become gradually weakened and finally be suppressed or lost.

With the purpose in mind to establish to my own satisfaction what can be accepted and what must be rejected regarding the various statements, theories and assumptions presented in the foregoing pages, I undertook a series of tests and experiments on selected cases of anomalous projection. These tests were either suggested by Verhoeff and others or were of my own original design.

The first half of the experiments was designed to either confirm or disprove Verhoeff's dictum that there can be no anomalous correspondence of disparate retinal termini. This statement, having been proved correct in every case under consideration, I aimed to establish by a set of entirely original experiments whether binocular vision in anomalous projection is based on somehow "correctly" inter-connected cortical termini of disparate retinal points in the two eyes or whether these stimuli are retained separately in the calcarine cortex and fused only through some such subconscious evaluation as suggested by Verhoeff or by the inactivity or suppression of the "stereoscopic cortical center" as promulgated by myself.

If such a new principle of cortical unification is acceptable, regardless of theoretical differences, together with the rejection of the existence of anomalous correspondence of retinal termini, anomalous projection requires an entirely different approach from the standpoint of orthoptics than has heretofore been employed. Patently, any training-device keeping the two visual fields separate (although identical) will then be of little use in these cases and methods of treatment based on these new principles will have to be devised.

PART TWO—CASE HISTORIES

The following are the case histories of the patients with anomalous projection reported in the subsequent experiments.

Case No. 1. B. H. female, age 15. Alternate estropia—anomalous projection.

B. H. and her younger sister D. H. came under my observation some seven years ago with histories of alternating squint without material reduction in visual acuity of either eye. This was undoubtedly of hereditary nature as their mother also has a left internal squint.

Examination of B. H. showed perfectly normal fundi, clear refractive medeae and concomitant convergent squint of 25° (as measured with the perimeter). There were no refractive defects and visual acuity 20/40 O. D. and 20/25 O. S. With the amblyoscope two dissimilar pictures (bird and cage) could be brought to close approximation but never superimposed. The amblyoscope showed an apparent squint of less than 10°. With the Kratometer similar results were obtained and there, too, the readings showed a much smaller deviation than was evident.

The case was diagnosed as alternate estoropia of hereditary origin with left dominancy and anomalous retinal correspondence. Orthoptic treatments were entirely unsuccessful in breaking up the anomalous "correspondence" but brought the visual acuity of the right eye from 20/40 to 20/30.

In January 1933 the angle of squint as determined by the stereocampimeter was found to be such that the blind spot of Mariotte of the squinting eye and the macula of the fixating eye were "corresponding" retinal points. In this connection a peculiar phenomenon was observed: While the left eye was fixing a minute white dot in the left fixation ring of Lloyd's standard campimeter chart and a 4° white test object was moved from the right temporal side of the chart toward the median septum, the test object intercepted the right blind spot at the exact position where the macula of that eye should have been and did not reappear until it had moved nasally a distance of 9°. As the blind spot of Mariotte was of normal size this could only mean that the patient involuntarily attempted to retain the 4° test object on the blind spot of the squinting eye in an effort to eliminate the presence of the large white disc occupying the same spatial position as the fixation object.

On the assumption that the patient might make some mental effort to hold on to this preferred position, she was asked to wear a pair of 4° prisms base-in for a period of several months with the expectation of an equal reduction in the convergent squint. This treatment proved unsuccessful in spite of the fact that a campimeter reading in May 1933 actually showed that, with the 8° prisms base-in, the macula-blind spot relationship still existed and therefore the squinting eye had straightened to compensate for the prisms. Alas, as soon as the glasses were removed the non-fixating eye turned nasally a distance of 4° and within the hour had assumed its original deviation. Glasses were therefore discontinued and the child discharged until further knowledge could be gained regarding treatment of anomalous correspondence.

In the summer of 1937 it was noted that B. H.'s turn had increased to slightly more than 20° so that the macula of one eye corresponded to an area slightly nasal to the blind spot of the other eye. Some further

experiments were conducted to determine to what extent binocular perception was present around the primary visual axis of the fixing eye: Beyond rivalry of color and very crude superposition of simple drawings nothing could be gained except the knowledge that there existed a slightly fluctuating but comparatively stable anomalous position between the two eyes (which was at the time considered proof of the presence of anomalous correct retinal correspondence).

Case No. 2. D. H. Sister of B. H., age 9. Alternate esotropia — anomalous projection.

D. H. came under by observation at the age of two when an alternate convergent strabismus of over 40° was noted. There seemed to be no particular preference as regards dominancy in the two eyes and refraction showed hyper-metropia of less than 2 dpts. Glasses were first prescribed at the age of three but without hope of influencing the squint to any extent. A decided shift of dominancy to the right eye had been noted and occasional occlusion of this eye was advocated. During the summer of 1935 a series of orthoptic treatments were given but it was evident that anomalous projection was so well established that two identical objects placed along the respective primary visual axes of the two eyes were invariably seen double. As the squint permanently remained at an angle of over 40°, tenotomy was advised in 1936 and carried out on September 23rd of this year. After operation the patient never experienced diplopia but the eyes, although able to straighten out completely, assumed a macula-blind spot relationship similar to that described in her sister's case.

Case No. 3. R. S., male, age 15. Right concomitant internal squint associated with anomalous projection.

This boy was first seen at my office at the age of seven. Examination showed a right concomitant internal squint of 30° with amblyopia (ex-anopsia?). Refraction gave O.D. +2.00D sph. $\bigcirc$ +1.50D cyl. axis 90. V.A. = 20/200 O.S. +1.50D sph. $\bigcirc$ +1.50D cyl. axis 90. V.A. = 20/40. Family history negative. Squint had been noticed from infancy. Attempts to improve the visual acuity of the right eye were unsuccessful. Best visual acuity attained 20/140. A positive macular blind spot in that eye was demonstrable. Orthoptic training with Mioculator, Kratometer, amblyoscope and other devices proved of little value. Occasional nystagmus in both eyes was observed when the boy was excited. Up to the present no great changes have occurred and visual acuity in the left eye remains subnormal (20/40) in spite of constant wearing of glasses.

Case No. 4 H. M., female, age 12. Left concomitant internal squint, anomalous projection.

This girl was brought to our attention at the age of eight with history of left esotropia since the age of two. No other squint cases in immediate family. Examination showed left concomitant internal

squint (30°) with left subnormal visual acuity. Refraction O.D. +3.00D sph. ⌒ +2.00D cyl. axis 105 V.A. = 20/20. O.S. +2.50D sph. ⌒ +2.50D cyl. axis 75V.A. = 20/80. Visual acuity was quickly brought up to 20/50+ but this proved another case where no amount of training seemed to affect the relative position of the two eyes.

PART THREE—EXPERIMENTS: FIRST SERIES

Consideration:

The first set of experimentations was designed to afford insight into the distribution and quality of monocular sensations brought to consciousness in the binocular visual perception of extrinsic objects in patients with anomalous projection.

Some of these experiments are adaptations of tests described by Verhoeff and Javal: others are of original design.

Simple tests were made to determine the function of the two foveae in squint cases with anomalous projections with particular reference to simultaneous macular perception.

EXPERIMENT ONE—*Test One*—Patient B. H., female, age 15 (Case History No. 1) alternate esotropia 15° to 25°.

V.A.—O. D. 20/25 +3) }
O. S. 20/20) } without correcting lenses.

Test Chart: White cardboard 5½x8″ with two extremely fine black lines running parallel (less than ½ mm. apart) up and down through the center of the chart.

This chart was held at a distance of 10 inches in front of the patient in an immovable position. The patient was then instructed to follow, first with the right and then the left eye, the tip of a pencil which was slowly moved across the chart from the right to the left of the central target. The girl was to "call out" when, while watching the pencil point, she could simultaneously distinguish the stationary target as a (distinct) double line.

Result: When the patient's right eye followed the pencil point from the right to the left side of the stationary target, she could distinguish the double line in two positions almost equally well and, so it appeared to her, she saw this target in both positions with the same eye. The two positions were: 1, the crossing point of the movable and stationary targets and, 2, when the pencil point was 40 to 44 mm. to the left of this point.

When the left eye followed the pencil point from the left side of the test chart across the double line to the right side, the patient distinguished the double line again at the crossing point and when the moving target was at a position of approximately 40 mm. to the right of this line. It seemed perfectly natural to the patient that this should be so. No sign of intermittency or alternation of vision was noted.

Test Two

Test Chart: White cardboard 5½x8" with two targets 40 mm. apart each consisting of two extremely fine black parallel lines ½ mm. apart and about 10 mm. in length. One was placed horizontally, the other vertically.

The chart was held at a distance of 10 inches in such a way that each primary visual axis of the two eyes intercepted one of the targets.

Result: Both targets were clearly and simultaneously seen as double lines. They appeared to the patient a "few inches" apart and no amount of coaxing could elicit any sensation of a cross or imperfect cross. When the patient was asked to watch first the one and then the other target with the same eye, no change in the relative position of the two targets in regard to each other was noticed, but when viewing the right target with the right eye or the left target with the left eye, the non-fixated target could only be distinguished as a blurred (single) line. The angle of squint was calculated to be approximately 22°.

Having ascertained simultaneous macular perception in this case, we undertook to investigate the following subects:

Test Three

D. H., sister of B. H., age 9 (Case history No. 2), alternate esotropia 15° after tenotomy.

V.A. with correction O.D. 20/20—O. S. 20/25. O.D slightly dominant.

Test Four

R. S., male, age 15 (Case history No. 3), right 20° esotropia.

V.A. with correction O.D. 6/60—O.S. 20/50. Right positive scotoma.

Test Five

H. M., female, age 12 (Case history No. 4), left concomitant squint. V.A. with correction O.D. 20/20-2—O.S. 20/50 + 1.

For this purpose the following test chart was used—

Test Chart: A rectangular black chart 5½" x 12" with two broad white rings of 18 mm. diameter set 116 mm. apart, leaving in each center a black area of 9 mm. width. In the upper half of the right black center a small letter "A" is drawn in white ink not more than 2½ mm. in height and a similar letter "B" is placed in the lower half of the left center.

The test was conducted in the following manner: The test chart was held slightly beyond the crossing point of the patient's visual axes and the latter was asked to focus with his (or her) dominant eye the letter (A or B) in whichever circle happened to be on the side of the squinting eye (left circle for right dominancy). The subject was instructed to keep a steady focus on that letter while the chart was slowly

withdrawn until suddenly the second letter appeared clearly visible. This position and the one, at a somewhat further distance, when the second letter again became indistinct were carefully recorded. Inasmuch as the two letters A and B were far apart and of comparatively small size, they could only be recognized simultaneously when the primary visual axes of the two eyes intercepted the two circles.

The results were as follows:

D. H. held the two targets on the respective maculae at all distances between 8″ and 17″ from her eyes. It was evident that the two eyes converged with the approach of the chart and relaxed convergence to the same extent as the target retreated.

R. S. on the other hand could not distinguish the second letter except when the chart was exactly 23″ from his eyes. The slightest change in position caused a blurring of that letter.

Both patients were at all times conscious of both circles in their absolute location.

This test was slightly altered in the case of *H. M.* because it was noticed that the test appeared to her somewhat confusing. The chart was, in this instance, held permanently in such a position that the crossed visual axes intercepted both targets. Mostly, the two circles appeared in proper spatial relation with both letters A and B plainly and simultaneously visible. As the patient kept gazing at the immovable targets, the circles, at rare occasions, seemed to be "as one." The patient was, however, very indefinite as to whether, at these moments, the circles had "fused" into one or were merely very close together. It was evident that this confusion caused her consternation.

These tests leave no doubt, that in *anomalous projection there are two areas of foveal perception in the binocular visual field.* The subjects credit their fixating eye for the vision in *both* of these areas and are perfectly aware of the greater or smaller (lateral) distance between them corresponding to the angular separation of the primary visual axes. For explanation of H. M.'s behavior further investigation seemed indicated.

EXPERIMENT TWO

The second experiment was undertaken to gain insight into the distribution of the binocular visual pattern between the fixating and squinting eyes. An exceedingly simple test, as suggested by Verhoeff, was employed and was conducted as follows:

The patient, wearing correcting lenses, had a red transparent screen placed in front of his dominant eye and a red-free (green) filter over the squinting eye. He was instructed to look at a red light (a light hardly visible through the green filter) 20 feet away while a brightly illuminated test chart consisting of a black cardboard with a one inch white square located centrally at the extreme upper edge, was placed at a distance of two feet in front of the patient in such a way that the red light serving as a fixation object for the dominant eye was seen directly above the

white square. The test chart was then steadily and slowly moved laterally toward and beyond the primary visual axis of the squinting eye and all apparent changes of color carefully noted.

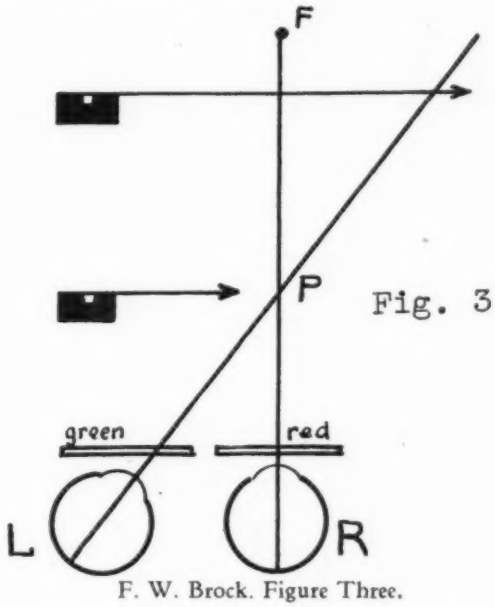

Fig. 3

F. W. Brock. Figure Three.

At no time was the fixating object permitted to swerve from the fixation object (red light).

The results obtained in the four cases under observation were as different as the individuals themselves. B. H. showed an almost even division of the binocular field between the two eyes; with the left eye focusing on the fixation object (red light), the movable target appeared red in the primary position and seemed to fade slightly as it moved toward the primary visual axis of the right eye. At approximately 7'' to 8'' from the starting point the target suddenly and completely changed from light red to light green, the latter intensifying somewhat as the target approached, and then reached, the right primary visual axis, located some 7'' further to the right. As the target was moved slowly and steadily back to its primary position, there was again a sudden and complete change in color midway between the two end-positions. No sign of rivalry nor any sign of partial replacement could be detected. The movement of the target appeared entirely steady and there was no hesitancy at any time which might have been interpreted as mental confusion.

The same experiment was repeated with the right eye dominant but the results did not vary in any particular.

The results obtained in examining all four patients are graphically

shown in Fig. No. 4. It can be readily seen that in the cases where the visual acuity in the two eyes does not differ greatly, the two eyes assume almost even responsibility in the "coverage" of the binocular visual field with none (B. H.) or only small areas of rivalry between them. In the two cases of D. H. and H. M. a transfer of fixation from the dominant to the non-dominant eye resulted in a material increase in the area covered by that eye, with an equivalent decrease in that of the other eye. In the case of (R. S.) where one eye is considerably subnormal, the dominant eye assumes almost complete supremacy in the entire binocular field.

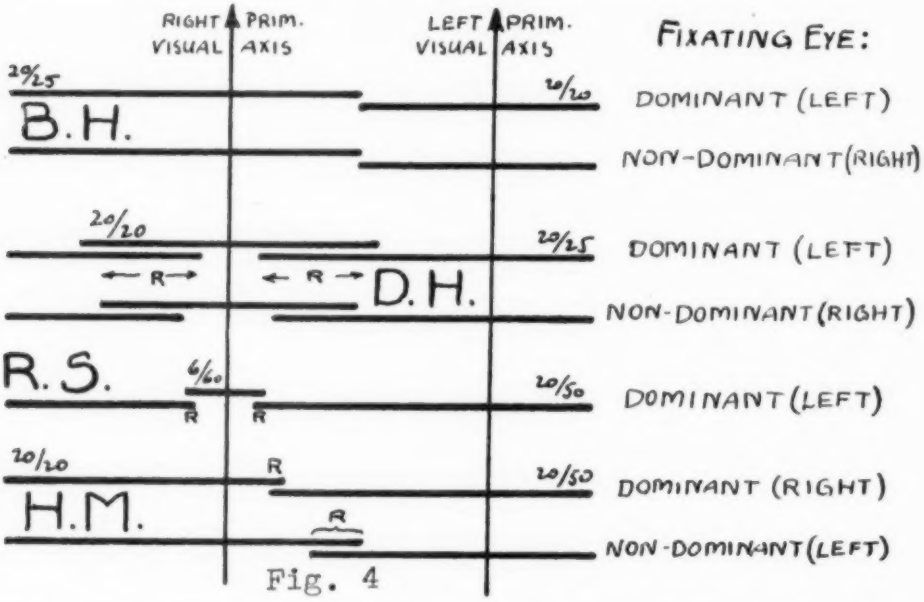

Fig. 4

F. W. Brock. Figure Four. Conscious binocular visual pattern in anomalous projection: the upper line (in each set) denotes areas in the visual field dominated by the right eye, the lower line that of the left. Rivalry (R) exists in overlapping areas. Figures denote visual acuity in the respective eyes.

A similar test through the crossing point P (Fig. No. 3) was made on patient H. M. with the result that there was marked and constant rivalry between red and green in all positions without any evidence of color blending.

The tests in this experiment prove that *in anomalous projection the distribution of conscious visual sensations in the binocular field is a matter of personal preference* with the individual patients *and not according to any set rule.* It would also indicate, in most cases, a decided difference in distribution of these areas with the change of fixation from one eye to the other. Therefore, Verhoeff's dictum that this distribution depends directly on the relative visual acuity of the disparate retinal points rivaling for dominancy, does not seem justified.

EXPERIMENT THREE

The results obtained in Experiment No. 2 would indicate that there is no conscious perception by the fixating eye in the area of the binocular visual field laying in juxta-position to the primary visual axis of the squinting eye. A further investigation into this phenomenon seemed desirable and the question was therefore approached from a different angle. For that purpose a black cardboard 7" x 13" with two white one-inch squares 165 mm. apart was designed. In the exact center of the one white square was a black letter "A" 3½ mm. overall, and in the center of the other a red dot, 6 mm. in diameter.

The chart was placed in front of the patient at the approximate crossing point of the primary visual axes in such a way that the letter "A" was on the same side as the squinting eye. The patient, wearing a red filter over his dominant and a red-free filter over his squinting eye, was instructed to focus the letter "A" with the former, while the chart was slowly and steadily moved further from him in such a way that, at some given distance *both* primary visual axes intercepted the two white squares respectively. The two filters caused the red dot to be but barely visible to the dominant eye while, when viewed through the squinting eye, it had the appearance of a purplish-black disc of great attention value.

The apparent color of the (red) dot and that of its (white) background were noted at all distances nearer, at, and further than, the distance where the two squares were intercepted by the visual axes of the two eyes as well as the manner in which they changed their color.

Results: In these tests the two squares seemed at all times in their true (absolute) position and the patients were never conscious of viewing either target with the squinting eye.

There were apparent gradual changes in the color of both the dot and its background. In the case of R. S., for instance, the background at 10" was quite red and the central dot just visible as a somewhat intensified red area. As the target retreated, the background faded to a pink and then to an almost white at a distance of 2 ft. At the same time the red dot gradually changed color and acquired an almost black appearance at the 2 foot level. From the 2 foot to the 38" position the reverse took place so that at the furthest position the background of the left target again was a definite red with a slightly intensified red central dot. On the other hand, in the case of D. H. the target appeared as a "purple" dot on a "reddish" background. All changes of color were gradual. When we compare these results with those obtained from the same subjects in experiment two, we find it difficult to account for the discrepancies. While R. S. had shown a conscious dominancy of the squinting eye in an angular area of less than 10° (around its primary visual axis) in the binocular visual field, with an almost sudden change occurring between

the dominancy of the two eyes, no such behavior could be ascertained in the above test. Here, on the contrary, there was a gradual change of color over a comparatively large (angular) area with definite color-mixture. This fact remained, however: all outlying areas of the binocular field were completely dominated by the fixating eye and the area immediately on and around the primary visual axis of the squinting eye was completely dominated by that eye.

Not so in the case of D. H. where in this area there seems to exist a conscious evaluation of bi-retinal stimuli coming from the macula of the squinting eye and the "corresponding" off-macular area of the fixating eye. Furthermore, here the squinting eye seems to retain its dominancy in the outlying binocular visual field on its side regardless of the fact that in the previous experiment no such behavior could be obtained.

This confirms, what already has been stated, that the binocular visual pattern in anomalous projection is an entirely individual matter and may vary, not only in each case under observation, but in the individual cases as well.

PART FOUR—CONCLUSIONS: FIRST SERIES—EXPERIMENTS

These experiments tend to verify the following facts:

1. Anomalous projection is fundamentally correct projection for patients with both alternating and monolateral squint. The term "false projection" is therefore inadmissable.

2. In anomalous projection there is *no* retinal correspondence, as pointed out by Verhoeff. The corresponding retinal axis of one eye intercepts innumerable points along the retinal axis of the other eye. Therefore, the terms "abnormal retinal correspondence," "secondary retinal correspondence," "false macula" are misleading.

3. In anomalous projection, where visual acuity of the two eyes permits, there are two areas of foveal perception in the binocular visual field. The subjects credit their fixing eye for the visual perception in both areas.

4. The common assumption that the functional changes that occur in cases of strabismus are suppression, defects in visual fields, amblyopia (as ex-anopsia) or anomalous projection (Shaad),[12] must be modified to the extent that anomalous projection may, and in the great majority of cases, does, exist together with the other functional changes mentioned.

5. For the above reason it can be safely stated that anomalous projection is a very much more common occurence in cases of squint than has heretofore been suspected.

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[12]Shaad, Dorothy J.: Binocular Vision and Orthoptic Procedure, Arch. Ophth. 20-477.

6. The assumption that there is no binocular simultaneous perception (Javal) in anomalous projection has been proved erroneous.

7. In anomalous projection strong rivalry may exist between the two eyes in certain areas of the binocular visual field and the non-dominant eye supplies a much greater part of the binocular visual pattern than is generally conceded.

8. A patient with anomalous projection may experience binocular mixture of color not only in the crossing point of his visual axes but also in other retinal areas.

9. In cases of anomalous projection where there is good visual acuity in both eyes the impressions produced in the macular areas of the two eyes by different objects are never suppressed; whereas, the other two retinal images of these objects are never consciously seen.

10. The abnormality in anomalous projection exists not in lack of simultaneous macula perception, but in the fact that both images are seen completely and that they are, as a rule, laterally separated from each other (Verhoeff).

11. In anomalous projection there can be stereoscopic vision beyond first degree fusion.

12. In anomalous projection the distribution of conscious visual sensations in the binocular field is a matter of individual "preference" and not according to any set rule.

How it is possible for strabismic patients to adapt themselves to such circumstances without totally suppressing the visual perception of the weaker eye and how they can possess some measure of depth perception greater than that obtained by occlusion of the squinting eye, are two questions worthy of further investigation.[13]

PART FIVE—EXPERIMENTS: SECOND SERIES

Consideration:

We know that in (normal) retinal correspondence the retinal sensations of the two eyes are in some way so unified in the occipital cortex that it is, as a rule, impossible for the individual to distinguish between sensations received binocularly or monocularly. Thus we are not conscious of the dividing line between our binocular and monocular visual fields. That this holds true for the macular region as well can easily be demonstrated by the following experiment: Create by some means a 10° exotropia in a subject with normal binocular vision and have him look at a distant point-source of light "A" (Fig. No. 5) with the right eye. This light is projected to the macula of the right eye (M R, A′ R) eye. This light is projected to the macula of the right eye (MR, A′R) (A′L) producing the sensation of two laterally separated lights AR and AL. The subject is now instructed to hold in each hand a suit-

[13]vide infra.

able object (B and C) such as an upright pencil and to move them at a distance of about 12" from widely separated positions on opposite sides of the visual lines nearer and nearer each other until they are in alignment with the two lights seen, AR and AL. Due to the fact that not only the light (A) but also the two objects B and C are seen double, this can be accomplished in several ways. However, the objects B and C will almost invariably be placed in such a position that the medially located images BL and CR are aligned with the two lights seen, AR and AL respectively. The subject is now under the definite impression that the object held in his right hand (C) is in line with the light to the right (AR) and the object in his left hand (B) is in direct line with the light off to the left (AL). In other words, he is

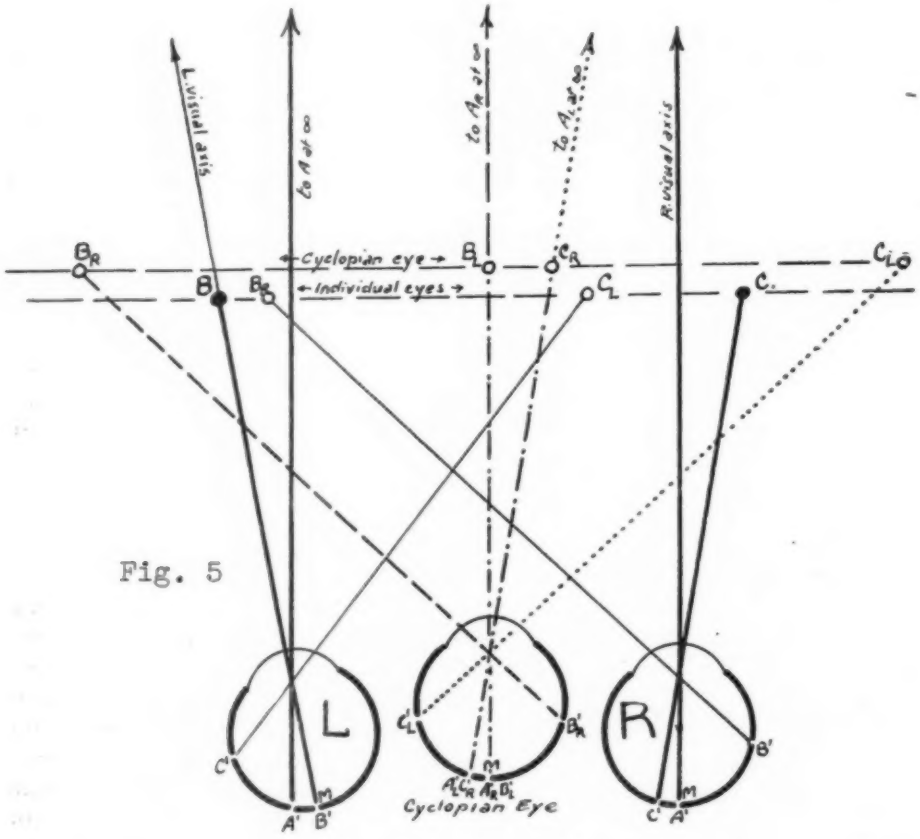


Fig. 5

F. W. Brock. Figure Five. Schematic representation of binocular orientation in a case of 10° exotropia with retinal correspondence while bringing two near objects (C and D) in alignment with both the macular (AR) and the off-foveal (AL) images of a far distant object (A). O denotes apparent (egocentric) positions of near objects: ● denotes absolute positions of near objects. Cyclopian eye shows how BL and CR (near objects) are in apparent alignment with AR and AL (far objects) respectively.

convinced that BL AR are on one visual axis while CR AL are located on the other (see cyclopean eye). The patient is invariably very much surprised when, by alternate occlusion, it is demonstrated that neither pencil is in line with either light! (Figure No. 5 shows how the two near objects seen with the right and left eye respectively are aligned with the distant objects, as seen by the opposite eyes.)

While in normal binocular vision there is complete unification of the two retinal perceptions it does not necessarily follow that the same is the case in anomalous projection. This is already suggested by the fact that the squinter of this class invariably refers all visual impressions to the fixating eye alone (Verhoeff) although the squinting eye is known to make valuable contributions in the mental evaluation of extrinsic objects. This seems to me a significant fact pointing to a very essential difference in the "mental hook-up" of the squinter.

I decided therefore to investigate further into this matter and chose as object for most of these further investigations the patient B. H. (case history No. 1) because she had proven in earlier experiments an unusual reliability and precise observation. At the same time, I considered her case as the purest type of anomalous projection without errors of refraction or subnormal vision in either eye.

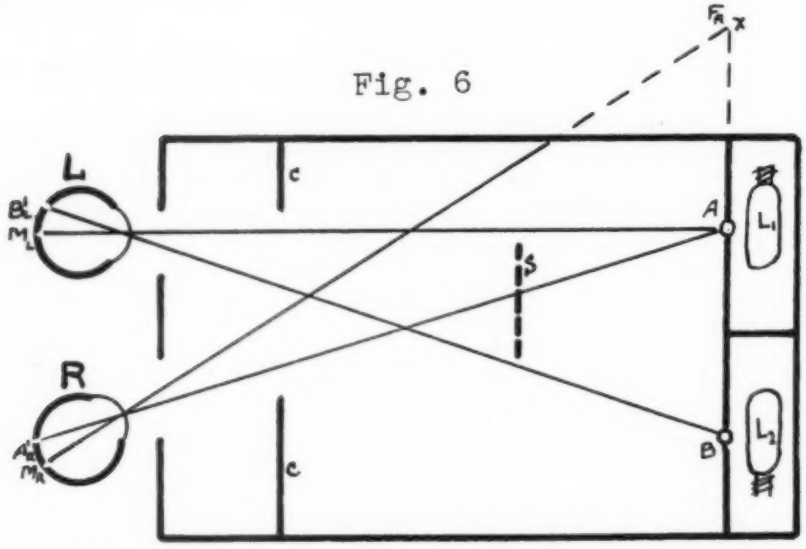
EXPERIMENT FOUR:

The purpose of this experiment was to simulate monocularly as closely as possible the binocular retinal sensation of B. H. while viewing a single object in space, in order to determine whether cortical interpretation would be identical in both instances. Apparatus, as depicted in Fig. No. 6 was therefore constructed, consisting of a black box of suitable size with two round openings cut in front permitting the patient to look into the box with both eyes. Two identical star shaped openings were cut in the farther end of the box, one (A) in approximately the primary visual axis of the dominant (left) eye and the other (B) at an angular distance (laterally from the first) equivalent to the patient's angle of squint. Blue translucent screens were placed behind these small star shaped openings and suitable lamps (L 1 and L 2) provided for their trans-illumination. A movable black shield (S) near the center of the box which, when brought into position, occluded the fixation object "A" from the squinting (right) eye, was synchronized with object "B" in such a way that it was in position whenever "B" was shown, and out of position when the lamp L 2 (illuminating object B) was turned off. A transverse septum "C" with suitable opening permanently occluded object "B" from the right eye.

With shield "S" out of position, object "A" illuminated, and "B" blackened out, the patient was instructed to fixate the blue star (A) directly in front of her. This star produced an off-foveal impression in the squinting eye nasalward just beyond the blind spot at a

point A'R which was (undoubtedly) projected to a point FR on the object-plane. The distance F R A being approximately equal to the separation of the two images "A" and "B." The binocular impression of object "A" should therefore have been very similar to the monocular impression produced in the right eye when both "A" and "B" were seen with that eye, provided fixation remained constantly at "A." To insure this, the flicker method was employed, showing the single object "A" or the double objects "A" and "B" for only a fraction of a second. Furthermore, the patient was kept completely unaware of the presence of the secondary object "B" at the beginning of the experiment. The result was conclusive in that the patient made no errors in judgment. Binocularly never more than one star was observed while monocularly the patient had invariably the impression of seeing two identical stars laterally separated.

Fig. 6



F. W. Brock. Figure Six. Testing apparatus used in experiment four.

The result of this test might be interpreted in favor of anomalous retinal correspondence but with all the mass of evidence against this type of correspondence of disparate retinal points another solution had to be found.

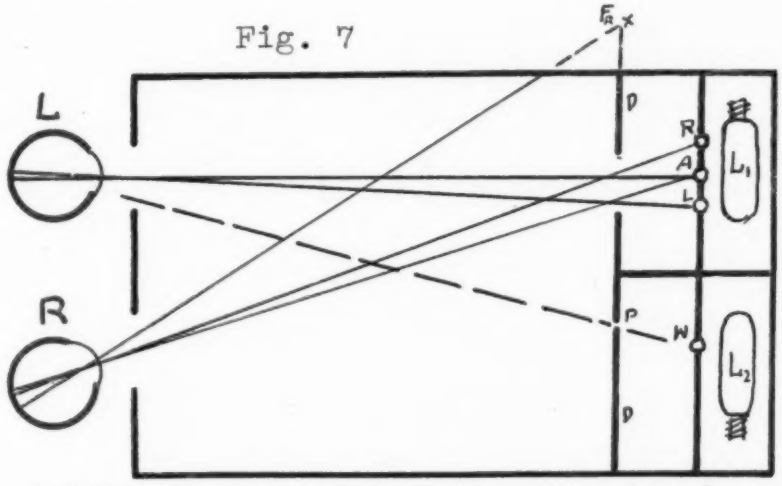
Having noticed, while examining patients with anomalous projection, a certain hesitancy and inconsistentcy in their evaluation of the binocular visual sensation, I undertook further tests on the assumption that, possibly, these patients do not mentally fuse the individual monocular visual sensation in the sense in which we understand fusion. If, for instance persons with normal binocular perception view a single extrinsic object with both eyes and a second identical object to the right

of the first with one eye only, two similar objects are seen which cannot be distinguished from each other. If now a third identical object, visible to the other eye only, is shown in line and immediately to the left of the other two, the remainder of the binocular visual field being entirely black, a person with well developed fusion will see three identical objects side by side, while a person with less developed fusion may, at the moment the third object is first shown, see three objects which immediately will melt into two, so that the binocularly visible object is fused with each of the two identical monocular objects. In a similar situation, patients with considerable lateral phorias may see two pairs of objects more or less widely separated which can with some effort be fused into one pair. What will happen in an experiment of this type applied to a person with anomalous projection was to be investigated by my next experiment.

EXPERIMENT FIVE:

For this purpose a black box, somewhat similar to the aforementioned but with different properties, was constructed (Fig. No. 7). Three small identical round openings (R, A, L) were cut in the far end of the box and a window was cut in a suitable transverse septum to permit object "A" and "L" to be seen by the left and "A" and "R" by the right eye only. Suitable slides (S, S) were provided to occlude or show objects "R" and "L" simultaneously or either one independently. All three objects, when visible, appeared as evenly trans-illuminated identical white discs.

Fig. 7



F. W. Brock. Figure Seven. "Fusion-Tester" used in experiment five.

In the first test the patient (B. H.) was instructed to focus the illuminated discs straight ahead with first one and then the other eye and to call out when she could distinguish more than one such disc. Either one, two, or three discs were then shown in irregular sequences.

Although there seemed to be no confusion and the answers were always the same in identical situations, the experiment proved inconclusive because the corresponding area in the squinting eye to the macula of the fixating eye lay so near the blind spot of Mariotte that one of the two lateral objects was invariably projected to the blind spot and consequently could not be seen.

To overcome this difficulty and to bring the images of the three test objects on retinal areas of approximately identical sensitivity, a pinhole (P) in the septum (D) and a small window (W) in the back wall of the box were placed in such a position that the lamp L_2 produced a minute luminous point at "P" which was visible only to the left eye and was situated in such a position that the two primary visual axes were equi-distant from the object "A" and on opposite sides. This luminous point (P) was used as fixation point during the rest of the experiment. The test was conducted first with the left and then the right eye fixating. In the latter case the box was merely used upside down.

The results are tabulated below. The capital letters show the sequence of targets shown. The circles indicated how they were interpreted and to what side of the fixation point (indicated by X).

LEFT Fixation		Point of fixation	RIGHT Fixation	
Test	Light sequence	Apparent position of objects	Light sequence	Test
a	R A	o o : o o	A L	f
b	A L	o o : o o	R A	g
c	R A (L)	o o : o o	(R) A L	h
d	(R) A L	o o : o o	R A (L)	i
e	R A L	o o : o o	R A L	k

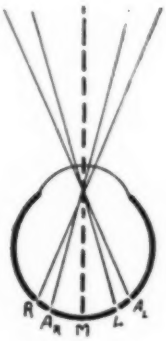


Fig. 8

F. W. Brock. Figure Eight. Cyclopean eye (right) showing the retinal points stimulated by all objects presented in experiment sixteen. Table (left) showing results obtained in experiment sixteen. All test series (a—k) started and ended with the single binocular disc A (position 1 and 3). In the intermediate position (2) one additional disc belonging to the right (R) or left (L) eye or both these discs were introduced for a fraction of a second. R A L denotes the presentation of all three objects in their respective positions relative to the fixation point X. : . shows position of additional disc relative to fixation object "o". (R) denotes reduction of illumination of disc R to be just barely perceptible.

In studying the chart and comparing it with Figure No. 8 representing all retinal points stimulated binocularly at one time or another by the centers of the three objects (A, R and L) it becomes plainly evident that the mental interpretation of bi-retinal stimuli is widely different in

a case of anomalous projection as compared with normal correspondence. In the sectional experiments a, c, d, e, f, h, i, and k (see chart) object "R" (right) in left fixation and object "L" (left) in right fixation were shown together with the binocularly visible object "A" and in all but two instances (sec. a and f) together with a third object of variable intensity belonging to the fixating eye only. It was interesting to note that the object seen monocularly by the squinting eye was only seen in its proper spatial relation when there was no second (identical) object visible to the fixating eye. As long as such an object was present, even though reduced in illumination to be barely visible, the two bright images of the squinting eye were mentally fused with the bright and dim objects of the fixating eye so that there appeared to be only two objects of similar intensity. Here again, there were no errors in judgment.

This fact proves definitely that no suppression of the "second" image of the non-dominant eye took place but that, as is the case with patients having poor fusion faculties, the binocularly visible object was fused with each of the monocular objects. This, once more, would be an excellent proof of the existence of secondary retinal correspondence of primarily disparate retinal points if, as is the case in patients with poor fusion or phorias, there would have appeared first, even for an instant only, three or four identical objects quickly merging into two. Considering the possibility of suppression of these "first impressions," I repeated the entire experiment using the flicker method previously mentioned. The results were identical.

Working on the theory (which I promulgated earlier) that the "fusion" of bi-retinal stimulations is accomplished by entirely different mental processes in subjects with anomalous projection than in those with (normal) retinal correspondence, I undertook a further experiment in an effort to establish the basic difference.

In experimenting with the above "Fusion Tester" (Fig. No. 7) on subjects with (normal) retinal correspondence, I had found that, when the monocularly visible discs "R" and "L" were colored red and yellow respectively, while the binocularly visible identical disc "A" remained white, there were again two more or less sharply defined groups which gave different results:

Group A, consisting of individuals with good fusion and well established accommodation-convergence relations experienced no greater difficulty in seeing the three discs in their actual positions than when all of them had been white.

Group B, consisting of subjects with poorly developed fusion and (in most cases) afflicted with considerable lateral phorias would fuse the binocularly visible white disc as long as it was presented alone or with one colored disc only (belonging either to the fixating or the squinting eye). As soon, however, as all three discs were presented simultaneously (two each to either eye), they would appear in their absolute position

(red, white and yellow) for a fraction of a second only and then quickly "melt" into two discs of less saturated color, exactly as they had done when all three had been white. In other words, in these cases, the desire to fuse objects of identical form although of different color and incorrectly related as far as absolute spatial position is concerned was far greater, than the desire to retain correct muscle balance and to keep the only binocularly visible object on the foveae of both eyes.

What, then, could be expected in a test of this order from patients with anomalous projection?

If their "fusion" is based on some form of mental judgment and a binocularly visible white disc has first been presented for "fusion," then it seems difficult to believe, when an additional red disc is presented to the fixing eye and a yellow one to the squinting eye on opposite sides of the fixation object, that they would be interpreted in the manner of Group B. Rather, one would expect a single unified white disc with the subsequent appearance of the two colored discs on either side thereof, as is the case in patients in Group A.

We would, in other words, expect the results to differ from that of experiment five although, as has been shown, in subjects with retinal correspondence the introduction of color in the monocularly visible discs does not bring about any such changes in the apparent position and number of objects shown.

To prevent any errors due to past experience and association I used another patient (H. M., case history No. 4) for this final experiment into the matter of fusion in anomalous projection.

EXPERIMENT SIX:

This experiment was conducted in identical fashion as the previous one with the one exception that in the first half of the test the object (R), visible to the right eye only, was colored red and the object (L), visible to the left eye only, was colored yellow.

Result: The results were as expected. All objects were seen in their respective positions, the red to the left and the yellow to the right of the white. Never were there seen two or four discs when all three were simultaneously shown! In other words, the mental interpretation was so correct that a person with the best of fusion could not have done better.

To determine in what way learning influences the binocular visual perception of patients with anomalous projection, this same patient (H. M.) was then subjected to the identical tests described in Experiment five.

The result of this test did not differ from the previous one (Experiment No. 6), the white objects simply replacing the colored ones of the previous experiment. The fact that H. M.'s interpretation differed so radically from B. H.'s did not come as a surprise but merely strengthened my conviction that *in anomalous projection there is no fusion* in the

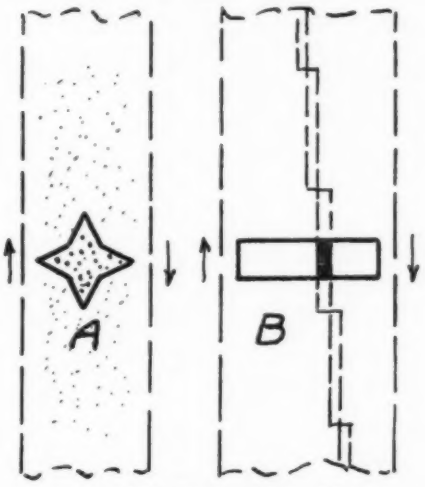
term in which fusion is almost universally accepted. It is therefore evident that, as Verhoeff suggested, another term such as *unification* should be applied to describe the mental process of unifying the binocular impressions.

The question of increased or reduced sensitivity (or alertness) in the off-foveal area of the squinting eye corresponding to the macula of the fixing eye was now taken under investigation in all the cases here described.

EXPERIMENT SEVEN:

For this purpose an "acuity tester" was devised, consisting of a black box similar to the one used in experiment four (Fig. No. 6) with the following exceptions: While a star-shaped cut-out in the back wall remained as a fixation object the colored transparency was removed and replaced by a movable translucent slide, covered with small dots in irregular arrangement (see Fig. No. 9-A). Thus, by moving the slide up and down, new groups of dots could be brought into the star-shaped opening.

Fig. 9



F. W. Brock. Figure Nine.

An oblong window (B) replaced the second star and the position of this window was made adjustable to the angle of squint. A moving slide produced, through the window, the effect of a vertical line constantly being replaced by a similar line in an exactly adjacent position either to the right or the left of the immediately preceding one. These "staggered" vertical lines (Fig. No. 9-B) were of different thicknesses in the various slides used and had a diameter of from 0.8 mm. to 1.6 mm. in intervals of 0.2 mm.

Test: Before any subject with anomalous projection was examined an approximate norm was established by measurements taken in a group of subjects with normal binocular vision and in similar off-foveal positions as those to be tested in the squinter. All patients with anomalous

projection were examined both in the area of the squinting eye "corresponding" to the macula of the fixing eye and in an equidistant area on the opposite side of its macula. Similar areas were examined in the fixating eye. To insure absolute and permanent fixation, the patient was instructed to count the minute dots showing in the star while the second slide (B) was moved. The thinnest line which could be discerned as showing any change in position was taken as a measure of visual acuity (or alertness).

Result: There was neither an increased nor decreased sensitivity of measurable amount of these off-foveal areas compared with:

A. off-foveal areas equidistant on opposite sides of the maculae of of the same patients;

B. equidistant off-foveal areas from the maculae of the other eyes of the same patients;

C. equidistant off-foveal areas from the maculae of control-groups of subjects with normal binocular vision.

Variations of perception were never more than ± 0.2 mm. from that of the established norm in any one of the subjects examined.

There still remained the investigation into the projection habits of patients with anomalous projection in order to ascertain how far expectancy of the patient is able to influence his interpretation of identical bi-retinal visual sensations; and, further, to determine the position of the primary visual axes of the two eyes relative to certain extrinsic objects permitting the most accurate orientation regarding these objects. For this purpose a "projection apparatus" was constructed as illustrated in Fig. 12 consisting of a black box with a central round opening 1½" in diameter in its front wall, with a septum extending medially to the back wall, dissecting the circular opening in the front (see Fig. No. 11). Two round translucent targets of different color were provided by circular openings in the back wall, equidistant and on opposite sides of the septum, and illuminated from the rear by two lamps (L_1L_2) which could be independently operated.

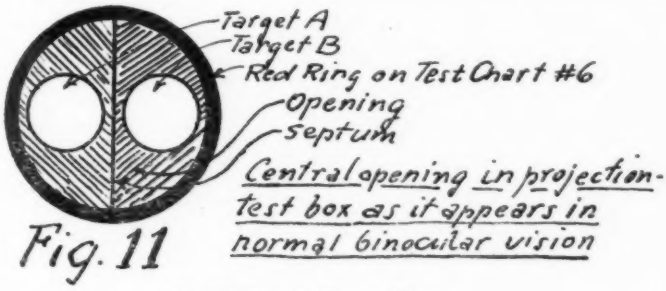
Fig. 10 TEST CHART No. 6

F. W. Brock. Figure Ten.

EXPERIMENT EIGHT Patient B. H. (case history No. 1):

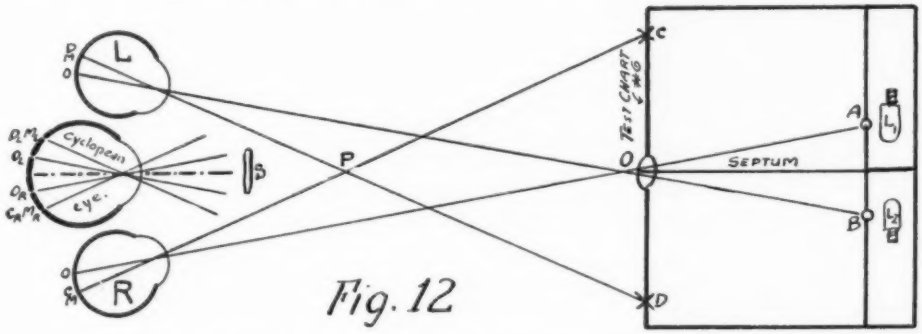
The patient to be tested was placed in such a position that, without

moving her head, she could see the left distant target (A) through the left half of the front opening (O) and the right distant target (B) through the right half of the same opening. This position was perma-



F. W. Brock. Figure Eleven.

nently retained with the aid of chin and forehead rests (S). A suitable test chart, such as test chart No. 6 (Fig. No. 10) with an opening corresponding to that of the box, was placed on the front wall and supplied with lateral targets (C and D) placed in such a position that the two primary visual axes of the squinter could be brought to intercept both these targets at one and the same time (see Fig. No. 12). While the patient's eyes were in such a position, the two distant targets "A" and "B" were flashed on and off and the patient's visual impressions recorded.



F. W. Brock. Figure Twelve. "Projection apparatus" used in experiment eight.

Result:

1. The extremely small letters (E) in the two front targets (C and D) were clearly and simultaneously visible.

2. The targets "C" and "D" appeared binocularly in the same apparent position as when viewed monocularly, the opening "O" lying centrally between them.

3. When the distant objects (A and B) were flashed on, both were simultaneously visible and appeared side by side within the central opening. Their edges were blurred and the color of the one seen by the dominant eye appeared more intense.

This certainly tends to prove that in anomalous projection there can be, under favorable conditions, a very accurate interpretation of bi-retinal stimuli. The only apparent difference between normal minocular vision and correct anomalous projection in this particular case is that in the former the two central targets "A" and "B" are seen clearly while the near targets "C" and "D" are blurred (as long as fixation remains within the central opening) and in the latter the two lateral (near) targets "C" and "D" are clearly visible while the centrally located targets are blurred.

Here again it would be easy to come to the conclusion that, in a case like this, there must exist anomalous correct retinal correspondence. That this conclusion would be falacious is definitely proven by the next and last experiment.

EXPERIMENT NINE:

This experiment was a direct continuation of the preceding one with no changes in the set-up except the removal of test-chart No. 6 and the replacement thereof by a plain white card of the same dimensions with a central hole for the front opening of the test box. The patient remained in the same position as before but was asked to look into the central opening.

Four separate tests were made as follows:

A. While the patient was focusing the illuminated distant target "B" (green disc) through the opening "O", target "A" (red disc) was intermittently illuminated with the result that while the green disc was clearly visible in the right half of the opening, the left half remained black and an indefinite red object seemed to "flash on and off at some distance to the left."

B. Here the patient focused on object "A" with his non-dominant eye while object "B" was intermittently shown. The result was similar to that in the previous test: the red target was clearly visible in the left semi-circle while the right half of the opening remained black. But again there was the sensation of an indefinite green object appearing and disappearing somewhere off to the right.

C. The patient was now asked to focus (with the dominant eye) on a small green target held against the edge of the septum in the exact center of the opening "O". Both distant targets "A" and "B" were momentarily shown and withdrawn by the flicker method with the result that target "B" (on line with fixation axis of the left eye) was clearly seen but that target "A" was observed only with difficulty and appeared "close by" but not in the opening "O".

D. The same experiment was repeated with the right eye fixating a 1° green test-target in the center of "O", and now both a clearly defined red disc and a somewhat unsteady green disc with blurred edges were visible, *one in each half of the central opening.*

While in all the tests conducted in Experiments eight and nine no

changes were made in the absolute or relative location of the three objects "A", "B" and "O" relative to each other and relative to the patient, yet their apparent position from the patient's point of view was widely different in the several tests.

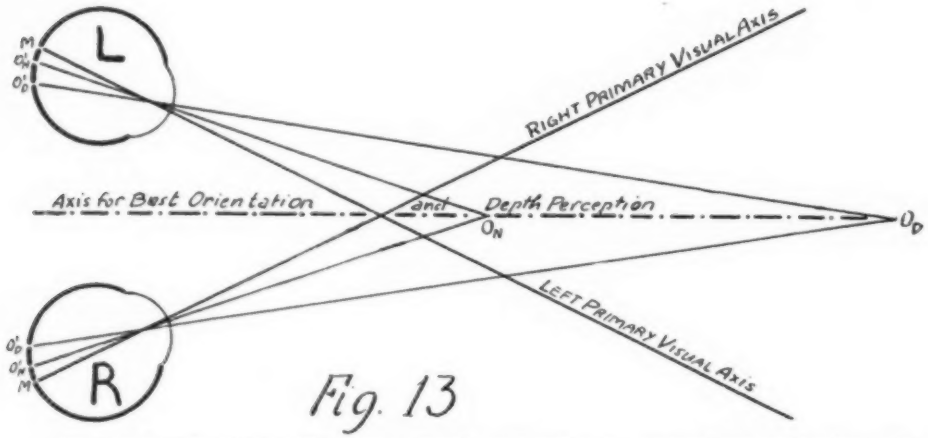
These tests prove that the most accurate spatial orientation, at least in the case under observation, was attained when neither primary visual axis bisected objects "A", "O" and "B" (Figure No. 12) whose absolute positions were under investigation, but rather when these objects (lying beyond the crossing point P) were situated approximately midway between these two axes. It appears then, that the patient judged the absolute position of the three objects by evaluating the disparatness of the off-foveal positions OL, OR of the retinal visual terminals stimulated by them. It seems significant that the best results were obtained when these points (OL, OR) fell on retinal terminals of approximately similar visual acuity, in other words, on retinal terminals equidistant but in opposite sides of the maculae of the two eyes. It has already been demonstrated that, in patients with anomalous projection, there are two laterally more or less separated regions in the binocular visual field where there exists simultaneous accurate (foveal) perception (Experiment No. 1). Furthermore, it must be accepted as a fact, that the angular distance between these two areas must remain constant for the proper evaluation of the position of extrinsic objects lying at any given distance from the observer.

Herring's drop test, which so successfully proved that patients with anomalous projection have a more accurate depth perception binocularly than with one eye occluded, further showed that best results were invariably obtained when the balls were dropped in a position approximately midway between the two primary visual axes of the two eyes. This tends to prove that *subjects with anomalous projection (and sufficient visual acuity in both eyes) seem to use as axis for the most accurate orientation and depth perception a line running from the median section of the head through the crossing point of the two primary visual axes.* This is decidedly at variance with Dr. Verhoeff's suggestion that orientation is along the primary visual axis of the fixating eye, and it is an observation which, I believe, has not previously been made.

Depth perception in anomalous projection seems to be accomplished by subconscious evaluation of the distance between the retinal terminals stimulated by these objects and the maculae of the two eyes. It is evident that the distance between the stimulated retinal points and the maculae are proportionately greater or smaller as the object lies farther or nearer along the orientation axis.

It becomes evident, therefore, that any change made (by whatever means) in the position of the primary visual axes relative to each other must affect the patient's judgment as to the absolute positions of all extrinsic objects. If, for instance, with the aid of prisms, orthoptic apparatus, or tenotomy, the two primary visual axes are brought into

coordinate positions, a single fixated object will be simultaneously presented to the patient's consciousness along the macular nerve fibres of both eyes.



F. W. Brock. Figure Thirteen. Depth perception in anomalous projection: the apparent distance of objects lying along the "orientation axis" may be gauged by the inter-macular distances MO'D and MO'N of the retinal stimuli received by the objects OD and ON respectively, on more or less identical off-foveal areas in the two eyes.

From previous experiences the patient has learned that simultaneous bimacular stimuli can only mean one of two things: that

1. The object viewed must lie at the crossing point of the primary visual axis: or that

2. There are actually two identical objects somewhere beyond the crossing point separated by an angular distance equivalent to the angle of squint. The absolute position of the object presented must furnish the clue as to which of the two interpretations seems correct. If there is no such clue, as in the after-image tests of Herring, the localization in outward space becomes exceedingly variable, as has been shown by experiments of Bielschowsky.

It has previously been demonstrated that in anomalous projection a single object in space lying beyond the crossing point of the primary visual axis of the fixing eye is *never* consciously seen by the squinting eye (conclusion No. 9, Experiments, 1st series). What inference the patient draws when a single object is projected along both primary visual axes from a distance obviously beyond the crossing point depends a great deal on his particular "type" of squint: A subject with monolateral squint is usually under the definite impression of seeing two laterally separated objects lying in the two macular areas of the binocular visual field; while subjects with alternate squint must deal with still another factor influencing their orientation. This added factor is the possible change of dominancy from one eye to the other without there being necessary any shift in the position of the two eyes relative to each other

and relative to the object. This (purely mental) change of dominancy has as result the apparent transfer of the "secondary" object from one side of the "fixated" object to the exactly opposite side and may therefore be interpreted as an additional (third) identical object in outer space. This undoubtedly was the case with the patient reported by Javal as experiencing binocular triplopia after tenotomy had been performed. It is evident that a subject with monolateral squint, whose eyes have been straightened by operative methods, has to learn an entirely new egocentric localization of objects lying along the primary visual axis of the formally squinting eye. Such a patient may, before this new orientation habit is thoroughly established, project a foveal stimulation (even on occlusion of the dominant eye) along both the former and present position of the primary axis of this eye, with resultant monocular diplopia such as has been reported by Javal and Von Gräfe.

Taking all the above into consideration, it becomes evident that: *immediately after tenotomy, or after any other method has been applied to bring the two primary visual axes into a parallel position, diplopia should be the rule and not the exception in patients with anomalous projection.*

In this connection it is therefore interesting to note how patient D. H. (case history No. 2) managed to evade the problem of double vision after tenotomy had been performed: simply by assuming a macula-blindspot relationship. This undoubtedly caused considerable consternation to the surgeon who had expected the eyes to "straighten" and found instead an esotropia of 15° to be present. However, to the patient, this slight turn meant complete relief from a very distressing and annoying sensation of double vision: because it again established a mono-macular consciousness of objects lying along the two fixation axes similar to the one she had enjoyed before the operation.

The fact that this patient eliminated all sensation of double vision by the mere acquisition of a macula-blindspot relationship is of very great importance. It must be assumed that if no such blind spots were present in her eyes the subject would undoubtedly have experienced uncrossed diplopia equivalent to the difference in her former and present angle of squint (45°—15°=30°). One would be inclined to assume that this conscious diplopia should extend over the whole of the binocular visual field. That this is not the case is proved by the fact that the elimination of two retinal areas no greater than the blind spot of Mariotte from the entire area of binocular perception has as result the complete cessation of all sensation of double vision. This tends to verify that: *in anomalous projection the conscious sensation of double vision is limited to a comparatively small area at and in close proximity of the two maculae, and that,* therefore, *simultaneous retinal perception* (on disparate retinal points) *may be expected in all retinal areas not very closely or directly corresponding with the macula of the other eye.*

Therefore, *in anomalous projection the off-foveal stimuli corresponding to the identical stimuli received on the macula of the other eye are the only retinal stimuli which must be totally suppressed in order to permit satisfactory binocular vision and orientation.*

PART SIX—CONCLUSIONS: SECOND SERIES—EXPERIMENTS

1. Subjects with anomalous projection (and sufficient visual acuity in both eyes) seem to use as axis for the most accurate orientation and depth perception a line running from the median section of the head through the crossing point of the two primary visual axes.

2. In anomalous projection there is no fusion in the true sense of the term, but merely a unification of binocular cortical impressions received along disparate nerve paths from the two retinae.

3. Neither is there an increase or decreased sensitivity in the off-foveal area of the squinting eye "corresponding" to the macula of the fixing eye.

4. Depth perception in anomalous projection seems to be accomplished by subconscious evaluation of the distance between the retinal terminals stimulated by these objects and the maculae of the two eyes.

5. In anomalous projection any change made, by whatever means, in the position of the primary visual axes relative to each other affects the patients' judgment regarding the absolute position of extrinsic objects.

6. Immediately after tenotomy, or after any other method has been applied to bring the two primary visual axes into a new relative position, diplopia should be considered the rule and not the exception in anomalous projection.

7. In anomalous projection the conscious sensation of double vision is limited to a comparatively small area at and in close proximity of the two maculae.

8. In anomalous projection simultaneous retinal perception (on disparate retinal points) may be expected in all retinal areas not very closely and not directly corresponding with the macula of the other eye.

9. In anomalous projection the off-foveal stimuli corresponding to the identical stimuli received on the macula of the other eye are the only retinal stimuli which must be totally suppressed in order to permit satisfactory binocular vision and orientation.

It is further suggested, partly on the strength of experimental evidence produced in this paper and partly on theoretical consideration that:

1. Normal binocular vision is the combined mental process of a dual system of fusion where unification of visual impressions is thought to be accomplished:

(a) through simple fusion of identical or nearly identical bi-retinal sensations by the phylogenetically older "fusion center" which affects a

conscious unified appreciation of the extrinsic world by subconscious mental evaluation of the separate (unfused) retinal stimuli.

(b) through stereoscopic fusion by the phylogenetically newer "center for stereopsis" necessitating an anatomically correct representation of nearly identical bi-retinal stimuli in the visual cortex. (It is thought that the effectiveness of this center does not extend far beyond the central area of the binocular visual field.)

2. Anomalous projection is, according to the aforementioned theory, the suppression or total absence of the anatomically exact process of stereoscopic fusion and the extension of conscious mental awareness of stimuli by the "fusion center" from the periphery to the central area of the binocular visional field.

3. Anomalous projection may be caused by:

(a) a complete and inherent absence of stereoscopic fusion (mostly hereditary in nature) without any other contributing causes.

(b) to a weak or (as in infants) undeveloped faculty for stereopsis coupled with some contributing cause or causes such as strong refractive defects, anisometropia, toxemia or children's diseases.

(c) to such extraneous causes alone, with subsequent amblyopia exanopsia of the squinting eye effecting in turn a diminished faculty for stereoscopic vision and eventual total loss thereof.

PART SEVEN—SUMMARY

All available facts regarding anomalous correct projection, abnormal retinal correspondence, false macula, false projection, secondary retinal correspondence, incongruous retinas, anomalous correspondence adapted to the angle of squint are presented and discussed.

Two sets of experimentations are conducted on patients with concomitant squint showing anomalous projection. On the strength of these experiments the following conclusions drawn by Verhoeff seem justified:

1. Anomalous projection is fundamentally correct projection for patients with both alternating and monolateral squint. The term "false projection" is therefore inadmissable. There is *no* retinal correspondence in these cases and therefore the terms "abnormal retinal correspondence," "secondary retinal correspondence," "false macula" are misleading. Further, anomalous projection may, and in the great majority of cases does, exist with suppression, amblyopia ex-anopsia and defects in visual fields and is a very much more common occurence in case of squint than has heretofore been suspected. Strong rivalry has been found between the two eyes in certain areas of the binocular visual pattern than is generally conceeded. The abnormality in anomalous projection exists not in lack of simultaneous macular perception but in the fact that both images are seen completely and that they are, as a rule, laterally separated from each other. There is never any stereoscopic vision beyond first degree fusion.

2. Original experiments (in series II) tend further to prove that

in squint cases with anomalous projection and good binocular visual acuity orientation and fixation are along different axes and that in all cases of anomalous projection there exists no fusion in the true sense of the term but only a unification of binocular cortical impressions through a subconscious mental evaluation based on judgment rather than definite "objective" knowledge. It has been shown that under certain conditions this avaluation of extrinsic objects may vary considerably without any change in the absolute position of these objects having occurred either relative to each other or relative to the patient's position.

3. Tests to determine the visual acuity in the off-foveal areas of the squinting eye corresponding to the macula of the fixating eye showed no material increase or decrease in acuity of perception compared with a similarly located area in opposite sides of the macula of either eye.

4. On the strength of the experimental evidence and theoretical consideration it is suggested that normal binocular vision is the combined mental process of a dual-system of fusion where unification in the periphery is thought to be accomplished by a center for fusion which is independent of innate retinal correspondence while fusion in the macular area, combined with stereopsis of greater or lesser degree, is accomplished by a "center for stereoscopic vision" with exact cortical spatial representation of conjugate retinal points by their cortical terminals.

It is further suggested, that according to this theory, primary anomalous projection is caused by the absence of stimuli from the phylogenatically newer "stereoscopic center" either with or without other contributing factors and that in concomitant squint due to refractive errors, toxemias or children's diseases, secondary anomalous projection may be brought about through the gradual suppression (usually associated with amblyopia ex-anopsia) and final total elimination of mental awareness of stimuli by the "center of sterescopic vision."

A more thorough investigation into the matter of fusion will be necessary before this dual-system of fusion can be definitely proposed as a "new fusion theory" in binocular vision. Further investigations along this line will be communicated in a later paper.

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THE TRUE OPTOMETRIC SPECIALIST

It is well to consider at times just what it is that leads men to enter the optometrical profession? In most cases it would seem that the modest goal is that of earning an honorable living. Some optometrists do cherish the ambition of contributing to the advancement of ocular knowledge and optical science, while in others is found the still loftier aim of serving their fellow men. Whatever may have guided our original impulse it is obvious that as optometrists we are engaged in a life long journey, along a trail which is leading us ever forward and along the paths of which are many pitfalls.

The optometrical profession functions as a restricted specialty in the general health field. This type of specialism is advantageous, but in the general health picture it also has its dangers. One is the tendency of the optometrist to lose the proper perspective of the patient as a whole. Another danger at times is the difficult job of keeping open the lines of communica-

tion between the optometrist and the general medical practitioner or the medical specialist.

There are two kinds of optometric specialists: the real and the false. The pseudospecialist extends his practice by astute canvassing. He is greedy of notoriety and eager for financial gain. He is neglectful of ethical standards and sometimes actually dishonest. We are unhappily familiar with the blatant commercially minded optometrist who prescribes glasses on every occasion and who boasts of "moving" such-and-such quantities of optical material in a given period of time.

The true optometric specialist is a man possessed of natural aptitude in ocular work who, after intensive training in this field, a training which necessitates dexterity in the manipulation of complicated apparatus, gradually attains to such a degree of skill and knowledge that he is deservedly recognized as a consultant in difficult and doubtful problems. The optometrical profession has the good fortune to possess many such men.

It is not difficult to recognize the true optometric specialist. He has certain characteristics which place him apart from the pseudospecialist. These characteristics are, first, that he is and remains as long as he is in practice, a student of his specialty. Second, he records his negative results or failures as scrupulously as he does his successes. Third, he is ready to submit his results to the control, reobservation and criticism by his colleagues through the medium of the papers he presents at meetings of his optometrical society and his published writings, and fourth, he is recognized also by his readiness to conform to the generally accepted professional standards demanded by the public of all professional people.

CAREL C. KOCH.

* * * * *

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